A STUDY OF THE FOOD VALUE
OF SIX VARIETIES OF
EDIBLE SOYBEANS

A THESIS

Submitted in partial fulfillment of the
requirements for the degree
of
Master of Science
in
Chemistry

by

James Thomas Waters Ross

Georgia School of Technology
Atlanta, Georgia

1940

ACKNOWLEDGEMENT

In the completion of this work, I should like to express my sincerest thanks to Prof. C. A. Wells, not only for his suggestion of the problem, but also for his most valuable aid and guidance in its prosecution. I should also like to thank Dr. G. H. Boggs and Prof. J. L.Daniel, of the Department of Chemistry, for their cooperation making it possible to pursue this study.

APPROVED

TABLE OF CONTENTS

PURPOSE

It does seem true that there is a great need in Georgia and some other parts of our country for improving the diet of our people. It is the purpose of this study to determine certain nutritive values in certain so-called edible soybeans, with the hope of shedding further light on the feasibility of using such beans as human food. With this objective in view six varieties of edible soybeans, recommended by the United States Department of Agriculture as being suitable for this geographic location, were obtained from that department and were grown by Prof. C. A. Wells in Habersham County, Georgia. Since these beans were grown on the same type of soil and under the same conditions, comparisons as to their yield and composition could be made.

These beans were analyzed for their protein, oil, calcium, iron, and phosphorus content; and these nutrients were evaluated in comparison with other common food substances. And it is pointed out that suitable soybeans and soybean products may become important constituents of low-cost diets.

A STUDY OF THE FOOD VALUES OF SIX VARIETIES OF EDIBLE SOYBEANS

With the widespread development in the use of soybeans in this country in recent years, the question as to the food value of this bean becomes one of great interest. In Oriental countries, especially China, Japan, and Manchuria, soybeans have been a chief constituent of the diet for centuries. However in this country the use of soybeans and soybean products in the human diet is relatively new.

The soybean was introduced into the United States as early as 1804, but for decades it was regarded as a botanical curiosity rather than as a plant of economic importance.[1] However since 1890 a great many of the United States experimental stations have experimented with soybeans, and much of the results have been published in the press and in scientific publications. With this increased interest in the soybean, there has likewise accompanied a rapid increase in the acreage of soybeans grown. Previous to 1917 considerable less than 500,000 acres were grown in this country. In 1924 there were more than 2,500,000 acres of soybeans grown.[2] In 1937 there were 6,982,000 acres of soybeans grown.[3] However with this great increase in production, the small country of Manchuria in 1936 produced about five times as many

---

1. W. J. Morse -- Soy beans -- Culture and Varieties Farmer's Bulletin No. 1520 - U.S. Dept. of Agri.
2. ibid.
3. E. W. Grove -- Soybeans in the United States; Recent Trends and Present Economic Status -- Bulletin -- 1938

soybeans as this country. But the acreage in this country is still increasing with improved methods and machinery for handling the crop and with the greater utilization of soybeans and its by-products for industrial purposes.

Since soybeans being so easy to grow and with favorable yield per acre, and since they have been used as a common food in the Oriental Countries of China, Japan, and Manchuria for centuries; the question naturally arises as to the value of soybeans as a human food in this country. The literature is replete with investigations of soybeans as a feed for livestock, and more recently a number of investigations have been made on the nutritive values for man. Daniels and Nichols[1], in 1917, by experimenting with rats, found that yellow soybeans yield a high percentage of physiologically good protein, a considerable amount of energy yielding materials in the form of fats and carbohydrates and a fairly liberal supply of fat soluble food accessory, as well as water soluble growth determinates. Dittes[2], in 1935, analyzed soybeans for their moisture, protein, fat, fiber, and ash content. Tuck, Manison, and Maynard[3] made a study of the food values of the proteins of soybean meal. In 1937, Hayward[4] studied the effects of the various means of oil extraction on the nutritive value of soybean meal. Also in this year, Shrewsbury and Vestal[5] made a study of the nutritive values and the

---

1. J. of Biol. Chem. 32, 91-102 -- 1917
2. J. Tenn. Acad. of Science 8, 323-25 -- 1935
3. J. Agriculture Research 51, 401-2 -- 1935
4. Oil and Soap 14, 317-21 -- 1937
5. Ind. Expt. Sta. Bulletin No. 420 -- 1937

mineral deficiences of soybeans. So quite a list of investigations carried out in this country can be cited on this problem. However the Chinese and Japanese have taken the lead in the study of this problem. In 1927 Howath[1] made a study of the food values, preparation, and uses of soybean oil. Ernst[2], in 1929, made a comparison of the nutritive values of soybean milk and cow's milk; and pointed out that soybean milk was richer in vitamin B, but was inferior in mineral content. Sking Wan[3] also worked on this subject, comparing soybean milk and cow's milk in vitamin B_1 and B_2 content; and he found soybeans to contain three times as much vitamin B_1, but only two-thirds as much vitamin B_2 as dried milk. Ivanovo[4], in 1935, studied the food value of soybeans determining the vitamin A, protein, and salt composition of the bean. Soybeans have also been studied as food for diabetic patients. In many instances investigators studied regular or field varieties of soybeans as suitable for human consumption, but in recent years there has been, as pointed out, an increased interest in the so-called edible varieties and their use as human food. A very comprehensive study is that of Woodruff and Klaas[5], at the University of Illinois, in which they made an investigation of seventeen varieties of edible

---

1. Howath -- Chinese Govt. Bureau of Economics -- 1927
2. Ernst -- Chinese Journal Physiol. -- 1929
3. Sking Wan -- Chinese Journal Physiol. -- 1929
4. Ivanovo -- Voprosui Pitaniya -- 1935
5. S. Woodruff and H. Klaas -- University of Illinois Agricultural Experimental Station Bulletin 443 -- 1938

soybeans with reference to their use as human food.

Since soybeans are adaptable to most types of soil in Georgia, and since they are very rich in protein; it seems that they would serve very well as what has been termed in the Orient "poor man's meat". It is not, however, the purpose of the investigation to list soybeans as chiefly a protein food, but rather to classify it as more nearly a "complete" food substance. That is, a food not only rich in proteins, but also fats and minerals. So it seems rather advantageous that soybeans should come to play a valuable role in low-cost diets. Professors Woodruff and Klaas[1] have stated the present importance of edible soybeans by saying that at the present the principal products of soybeans are salad oil, made from refined soybean oil; and hydrogenated margarines and shortenings. The amount of soybean flour used in food manufacture is also significant. And the long list of food novelties which derive more or less of their substance from soybeans indicate the versatile use of the bean. But considering these many uses, soybeans today constitute only a small part of the nation's diet.

In our investigation a study has been made of the moisture, calcium, iron, phosphorus, protein, and fat content of six varieties of edible soybeans grown in Georgia[2]. And these values are compared with certain other foods. Since these beans were grown in this state, it was possible to calculate their

---

1. Univ. of Ill. Agri. Expt. Sta. Bulletin 443 -- 1938
2. The seed beans for this investigation were recommended and and supplied by the United States Department of Agriculture. However the beans were grown by Prof. C.A. Wells during the year of 1939 in North Georgia.

yield on this type of soil and to predict the best probable variety to be grown in this section with regard to the food value of the bean and its yield per acre.

EXPERIMENTAL

GENERAL APPEARANCE OF THE DRY BEANS

In this investigation the six varieties of beans studied were Higan, Imperial, Rokusum, Easycook, Nanda, and Seminole. Of these the first varieties to mature were Higan and Imperial, and these varieties were dry enough to harvest two weeks before any of the others. Rokusum and Easycook were the next varieties to mature, and Nanda and Seminole matured last.

Table No. 1 Dates of planting and harvesting of the beans.

Variety	Date of Planting	Date of Harvesting
Higan	June 1, 1939	Sept. 10, 1939
Imperial	June 1, 1939	Sept. 10, 1939
Rokusum	June 1, 1939	Oct. 1, 1939
Easycook	June 1, 1939	Oct. 1, 1939
Nanda	June 1, 1939	Oct. 20, 1939
Seminole	June 1, 1939	Oct. 20, 1939

All of these beans were the yellow varieties, for it is these varieties which are generally preferred for edible purposes. The beans range in size from very small to comparatively large. As is shown in the following table, Rokusum soybeans are the large type; much larger than any other variety studied. Imperial and Nanda are, what may be called, an average size bean. Higan and Easycook are varieties of comparatively small beans, with Easycook being the smallest. The Seminole variety varied in size from very small to very large.

Table No. 2 Comparative size of beans.

Variety	Number of beans per 25 gram sample
Higan	119
Imperial	90
Rokusum	83
Easycook	166
Nanda	108
Seminole	116

YIELD

This study of the yield is not based upon actual yield per acre, but is rather a calculated result based upon much smaller plot yields. Even though calculated from small plot productions the results, nevertheless, indicate the approximate yield per acre of the different varieties grown.

Table No. 3 Yield per acre

Variety	No. of vines Harvested	Yield (Grams)	Yield per Acre (30" by 8")
Higan	83	1554	14.3 Bu.
Imperial	57	1183	15.6 Bu.
Rokusum	58	1323	17.4 Bu.
Easycook	99	2504	19.3 Bu.
Nanda	62	999	12.3 Bu.
Seminole	38	345	6.9 Bu.

From the above table one observes that the earlier maturing varieties give also the heaviest yields. This is con- to the behavior of certain plants such as oats and corn.

It is generally true that the longest maturing variety gives the highest yield; though, of course, other factors enter into the question of quantity production. It would seem that the Easycook variety is the best adapted to the soil and climatic conditions in North-East Georgia. Rokusum, however , is a very close second. The Seminole variety in this test proved least desirable both as to yield and as to period of maturity. On the whole it would seem that edible soybeans are easily grown and well adapted to this section of our country.

DETERMINATION OF MOISTURE CONTENT

The beans were first ground in a burr mill. After this the meal was pulverized to a very fine powder with an agate mortar and pestle. It was then weighed and dried in an oven to constant weight. This drying required twenty hours. The first sixteen of which the meal was dried at a temperature of 100-105 degrees Centigrade. After this the temperature was lowered to 90-95 degrees Centigrade because previous trials had shown that this was necessary to prevent overheating, or scorching. This meal was then weighed and heated for another period of two hours at the above temperature so as to assure constant weight.Prior to this determination of moisture, the soybeans were first air-dried; except the Seminole variety which was not air-dried as much, and for that reason it showed greater loss of weight on oven drying. It was necessary to determine the effect of air-drying on the moisture content so as to be able to make latter calculations on a completely dry basis.

Table No. 4 Percentage change in weifht with air-drying

Variety	Nov. 13 Weight	Jan. 6 Weight	% loss	Feb. 8 Weight	% loss	Mar. 24 Weight	% loss
Higan	25.0656	24.3744	2.75	24.2159	3.39	24.3674	2.79
Imperial		25.0139		24.7319	1.12	24.8677	.59
Rokusum	25.1466	24.2352	3.62	24.0894	4.20	24.2358	3.61
Easycook		25.0448		24.8294	.86	24.9506	.37
Nanda		25.0215		24.6827	1.35	24.8351	.74
Seminole	25.0348	22.3765	10.61	22.2365	11.21	22.3707	10.64

The loss of moisture from November to February is as would be expected, but one has no explanation for the increase in moisture from winter to spring.

Table No. 5 Moisture content

Variety	Weight of sample before heating	Weight of sample after heating	Weight of moisture	Percentage moisture
Higan	15.2535	14.0595	1.1940	8.10
	14.6431	13.4953	1.1478	8.12
Imperial	7.2811	6.8307	.4504	6.18
	9.7130	9.1108	.6022	6.19
Rokusum	11.4384	10.5115	.9269	8.10
	12.0051	11.0283	.9768	8.12
Easycook	11.1281	10.4650	.6631	5.95
	7.5171	7.0645	.4526	6.02
Nanda	7.5361	7.0758	.4623	6.13
	8.5605	8.0358	.5247	6.13
Seminole	14.1989	11.9612	2.2377	15.76
	12.9891	10.9732	2.0159	15.52

Since the moisture content varies with the length of time which the beans are left to air-dry it is apparent that the percentage of moisture, determined either by air-drying or in an oven, will depend upon the age of the bean at the time of starting the determination. From the maturing of the beans until they are shelled, as well as after hulling, the drying out process goes on. This explains why the Seminole variety shows a relatively high percentage of moisture - simply because it had not aged (dried) as much as the other varieties up to the time samples were taken for moisture determinations.

DETERMINATION OF IRON
(Colorimetric Method)

The beans were ground in a mortar and pestle. The meal to be analyzed was weighed out into 250 ml. pyrex beakers. It was then moistened with conc. HNO_3 so as to help destroy organic matter, and dried at a temperature of 180 degrees Centigrade for two hours. The black mass was then ignited in a muffle furance at a temperature of 600 degrees Centigrade for a period of six hours. The ash was then completely white. If the ash was not white, it was moistened with conc. HNO_3 and ignited again. After ignition the ash was dissolved in dilute HCl, and then treated with H_2SO_4 and heated to remove the chlorides. The solution was then neutralized with NH_4OH* and made slightly acidic with dilute H_2SO_4. The volume was then built up to 250 ml. and just sufficient dilute $KMnO_4$ was added to insure

* At this point a white gelatinous precipitate usually appears. This is probably due to the precipitation of the calcium and the phosphates in a basic solution.

complete oxidation of the iron. Potassium thiocyanate solution was then added and the solution was immediately compared with that of a known iron concentration by means of a colorimeter.

Solutions used:

1. Standard iron solution:

   This standard iron solution had to be very dilute as the percentage of iron in soybeans is very low. For this purpose .05 grams of ferrous ammonium sulfate of known purity was dissolved in a liter of water.

2. Potassium Thiocyanate solution:

   This solution was of the concentration of 20 grams of salt per liter of water.

3. Dilute Hydrochloric Acid:

   The concentrated acid was diluted with an equal volume of water.

4. Potassium Permanganate solution:

   This solution was about 0.01 Normal.

Table No. 6 The iron content of Higan Soybeans.

Weight of sample	Depth (mm.) (Standard)	Depth (mm.) (Soybeans)	Ratio	Grs. Fe.	%(Dry)	%(Air* Dry)
1. 9.8227 (on dry basis)	15	39	1:2.60	.00070	.0072	.0065
	12	33	1:2.75	.00064	.0065	.0060
10.6560 (on air-dry basis)	10	28	1:2.80	.00062	.0063	.0058
	15	36	1:2.40	.00074	.0075	.0069
	12	30	1:2.50	.00071	.0072	.0065
	10	23	1:2.30	.00076	.0077	.0071
2. 10.3103	15	35	1:2.33	.00076	.0073	.0068
	12	30	1:2.50	.00071	.0068	.0064
11.1849	10	22	1:2.20	.00081	.0077	.0072
	15	34	1:2.26	.00077	.0073	.0068
	12	31	1:2.41	.00074	.0071	.0066
	10	25	1:2.50	.00071	.0068	.0064
3. 10.7148	15	34	1:2.26	.00079	.0073	.0068
	12	27	1:2.23	.00080	.0074	.0069
11.6227	10	24	1:2.40	.00074	.0069	.0064
	15	35	1:2.33	.00076	.0070	.0066
	12	28	1:2.33	.00076	.0070	.0066
	10	25	1:2.50	.00071	.0066	.0061

The average percentage of iron on a dry basis is 0.0071.

The average percentage of iron on an air-dry basis is 0.0066.

* Air-dry as of February 8 (Table No. 4)

Table No. 7 The iron content of Imperial Soybeans.

Weight of sample	Depth (mm.) (Standard)	Depth (mm.) (Soybeans)	Ratio	Grs. Fe.	%(Dry)	%(Air-Dry*)
1. 19.0053 (on dry basis)	20	44	1:2.20	.00081	.0042	.0040
	15	32	1:2.13	.00083	.0043	.0040
20.1327 (on air-dry basis)	10	21	1:2.10	.00083	.0043	.0041
	20	43	1:2.15	.00082	.0042	.0040
	15	31	1:2.06	.00085	.0044	.0042
	10	22	1:2.20	.00081	.0042	.0040
2. 19.3399	20	42	1:2.10	.00083	.0042	.0040
20.4871	15	32	1:2.13	.00083	.0042	.0040
	10	22	1:2.20	.00081	.0041	.0040
	20	42	1:2.10	.00083	.0042	.0040
	15	31	1:2.06	.00085	.0044	.0042
	10	20	1:2.00	.00088	.0046	.0043
3. 19.5034	20	41	1:2.05	.00085	.0044	.0042
20.6604	15	30	1:2.00	.00088	.0045	.0043
	10	20	1:2.00	.00088	.0045	.0043
	20	41	1:2.05	.00085	.0044	.0042
	15	30	1:2.00	.00088	.0045	.0043
	10	20	1:2.00	.00088	.0045	.0043

The average percentage of iron on a dry basis is 0.0043.

The average percentage of iron on an air-dry basis is 0.0041

* Air-dry as of February 8 (table 4)

Table No. 8 The iron content of Rokusum Soybeans.

Weight of sample	Depth(mm.) (Standard)	Depth(mm.) (Soybeans)	Ratio	Grs. Fe.	%(Dry)	%(Air-Dry*)
1. 10.1786 (On dry basis)	15	33	1:2.22	.00080	.0078	.0072
	12	25	1:2.08	.00085	.0083	.0076
11.0769 (On air-dry basis)	10	22	1:2.20	.00081	.0079	.0072
	15	34	1:2.26	.00077	.0075	.0070
	12	26	1:2.17	.00082	.0080	.0073
	10	23	1:2.30	.00076	.0074	.0069
2. 10.1070	15	35	1:2.33	.00076	.0075	.0070
	12	27	1:2.25	.00079	.0078	.0072
10.9990	10	21	1:2.10	.00083	.0082	.0076
	15	32	1:2.13	.00083	.0082	.0076
	12	24	1:2.00	.00088	.0087	.0079
	10	20	1:2.00	.00088	.0087	.0079
3. 10.4150	15	34	1:2.26	.00079	.0076	.0070
	12	26	1:2.17	.00082	.0078	.0072
11.3342	10	21	1:2.10	.00083	.0079	.0072
	15	36	1:2.40	.00074	.0071	.0065
	12	27	1:2.22	.00080	.0076	.0070
	10	23	1:2.30	.00076	.0073	.0067

The average percentage of iron on a dry basis is 0.0078.

The average percentage of iron on an air-dry basis is 0.0072

* Air-dry as of February 8 (Table No. 4)

Table No. 9 The Iron content of Easycook Soybeans.

Weight of sample	Depth (mm.) (Standard)	Depth (mm.) (Soybeans)	Ratio	Grs. Fe.	%(Dry)	%(Air-Dry*)
1. 17.3232 (On dry	20	45	1:2.25	.00077	.0046	.0042
basis)	15	34	1:2.26	.00079	.0046	.0042
18.3664 (On air-	10	27	1:2.70	.00067	.0039	.0036
dry basis)	20	47	1:2.35	.00077	.0045	.0042
	15	35	1:2.36	.00077	.0045	.0042
	10	25	1:2.50	.00071	.0041	.0038
2. 16.6016	20	48	1:2.40	.00074	.0044	.0042
	15	38	1:2.50	.00071	.0042	.0040
17.6016	10	28	1:2.80	.00062	.0037	.0035
	20	49	1:2.45	.00070	.0042	.0040
	15	37	1:2.46	.00070	.0042	.0040
	10	28	1:2.80	.00062	.0037	.0035
3. 17.3606	20	47	1:2.35	.00076	.0045	.0042
	15	37	1:2.46	.00070	.0042	.0039
18.4061	10	28	1:2.80	.00062	.0037	.0033
	20	48	1:2.40	.00074	.0044	.0041
	15	34	1:2.26	.00077	.0046	.0042
	10	24	1:2.40	.00074	.0044	.0041

The average percentage of iron on a dry basis is 0.0042.

The average percentage of iron on an air-dry basis is 0.0040.

* Air-dry as of February 8 (Table No. 4)

Table No. 10 The iron content of Nanda Soybeans.

Weight of sample	Depth (mm.) (Standard)	Depth (mm.) (Soybeans)	Ratio	Grs. Fe.	%(Dry)	%(air* dry)
1. 17.6008 (On dry basis) 18.5976 (On air-dry basis)	20	48	1:2.40	.00074	.0042	.0039
	15	35	1:2.35	.00077	.0044	.0041
	10	25	1:2.50	.00071	.0040	.0038
	20	47	1:2.35	.00077	.0044	.0041
	15	37	1:2.45	.00073	.0042	.0039
	10	25	1:2.50	.00071	.0040	.0038
2. 17.2909 18.2702	20	48	1:2.40	.00074	.0042	.0040
	15	39	1:2.60	.00069	.0039	.0037
	10	26	1:2.60	.00069	.0039	.0037
	20	49	1:2.45	.00073	.0042	.0040
	15	37	1:2.45	.00073	.0042	.0040
	10	26	1:2.60	.00069	.0039	.0037
3. 17.4605 18.4492	20	50	1:2.50	.00071	.0040	.0038
	15	39	1:2.60	.00069	.0039	.0037
	10	28	1:2.80	.00062	.0036	.0033
	20	50	1:2.50	.00071	.0040	.0038
	15	38	1:2.50	.00071	.0040	.0038
	10	26	1:2.60	.00069	.0039	.0037

The average perecntage of iron on a dry basis is 0.0040.

The average percentage of iron on an air dry basis is 0.0038.

* Air-dry as of February 8 (Table No. 4)

Table No. 11 The iron content of Seminole Soybeans.

Weight of sample	Depth (mm.) (Standard)	Depth(mm.) (Soybeans)	Ratio	Grs. Fe.	%(Dry)	%(Air Dry*)
1. 7.4244 (On dry basis)	15	50	1:3.33	.00052	.0070	.0059
	12	43	1:3.58	.00049	.0065	.0055
8.8008 (On air-dry basis)	10	39	1:3.90	.00045	.0060	.0051
	15	49	1:3.33	.00051	.0069	.0059
	12	41	1:3.42	.00050	.0067	.0058
	10	38	1:3.80	.00046	.0061	.0052
2. 7.5354	15	50	1:3.33	.00052	.0069	.0058
	12	40	1:3.33	.00052	.0069	.0058
8.9324	10	37	1:3.70	.00048	.0063	.0054
	15	50	1:3.33	.00052	.0069	.0058
	12	40	1:3.33	.00052	.0069	.0058
	10	35	1:3.50	.00050	.0066	.0056
3. 7.6132	15	50	1:3.33	.00052	.0068	.0057
	12	42	1:3.50	.00050	.0065	.0055
9.0246	10	39	1:3.90	.00045	.0059	.0049
	15	48	1:3.30	.00052	.0068	.0057
	12	41	1:3.42	.00050	.0065	.0055
	10	38	1:3.80	.00046	.0060	.0050

The average percentage of iron on a dry basis is 0.0065.

The average percentage of iron an an air dry basis is 0.0055.

* Air-dry as of February 8 (Table No. 4)

DETERMINATION OF PHOSPHORUS

Method: (Standard method for the determining of phosphorus as $Mg_2P_2O_7$*.) A sample of about 10 grams of the bean meal was weighed and placed into a 1 liter erlenmeyer flask. To this was added 25 ml. of conc. HNO_3 and 25 ml. of 0.5 N $KMnO_4$[1]. 80 ml. of conc. H_2SO_4 was then added and the mixture heated gently for one-half an hour. After this period the heat was increased and KNO_3 was added in small quantities until the solution was clear. (This period of digestion usually required 4-5 hours.) The solution was then transferred to a 1 liter volumetric flask and diluted to a liter. The phosphorus was then determined in a 250 ml. aliquot portion of this sample.

To this aliquot was added 10 ml. of conc. HNO_3. NH_4OH was then added to the solution until it was neutral, and then the solution was made just barely acidic with dilute HNO_3. It was then diluted to 500 ml. and warmed to 25-30 degrees. To this warm solution was added 75-100 ml. of the molybdate solution[2] and the contents shaken for 30-45 minutes. The solution was then decanted and filtered, and the Y.P.[3] was first washed

---

* This procedure was adapted from Fales.

1. The $KMnO_4$ is added to oxidize the phosphides as HNO_3 is not sufficient for this purpose, and as a result some of the phosphorus would come off as phosphine.
2. Molybdate solution: 30 grams of 85% molybdic acid was dissolved in 38 ml. of conc. NH_4OH and 68 ml. of water. The solution was cooled and poured slowly, with stirring, into 122 ml. of conc. HNO_3 and 287 ml. of water. It was then left to stand over-night before using.
3. Y.P. -- Ammonium phospho-molybdate.

with 0.1 N HNO_3 solution in order to wash it free of iron and molybdenum, and then washed with 0.1 N KNO_3 solution so as to remove the HNO_3 left from the previous washings.

The Y.P. was then dissolved in 30 ml. of 2.5 N NH_4OH and the filter paper washed. (The filtrate did not exceed 100 ml) The solution was made slightly acidic to litmus with 3 N HCl and cooled to 25-30 degrees. Magnesia mixture was then added drop by drop with constant stirring until a moderate excess was present. (The excess was about 4 ml. over the amount calculated on the basis of 1 ml. of the magnesia mixture for each 4 mg. of phosphorus present.) After the addition of the magnesia mixture an amount of 15 N NH_4OH was added to the solution so that the final concentration of the NH_4OH was about 1.5 N. This was then allowed to stand at room temperature for four hours.

Since the precipitate of magnesium ammomium phosphate may be contaminated with molybdenum redissolving and reprecipitation was carried out. This final solution was then filtered and the residue washed with 1.5 N NH_4OH. The magnesium ammonium phosphate so obtained was ignited to constant weight and weighed as $Mg_2P_2O_7$.

Table No. 12 Phosphorus content.

Variety		Weight of sample (dry)	Weight of $Mg_2P_2O_7$	Weight of Phosphorus	Percent (dry)	Percent (air-dry)
Higan	(1)	3.8309	.0951	.02646	.693	.636
	(2)	3.7776	.0962	.02677	.708	.653
	(3)	3.2174	.0826	.02298	.714	.658
Imperial	(1)	4.1085	.1104	.03072	.747	.701
	(2)	4.0753	.1097	.03053	.749	.702
	(3)	3.9977	.1067	.02969	.742	.697
Rokusum	(1)	3.9556	.0957	.02663	.673	.618
	(2)	3.9732	.0978	.02722	.657	.605
	(3)	4.1699	.0939	.02613	.652	.602
Easycook	(1)	3.3428	.0822	.02287	.684	.642
	(2)	3.9424	.0961	.02674	.678	.637
	(3)	3.6028	.0917	.02552	.708	.663
Nanda	(1)	4.2127	.0903	.02513	.596	.559
	(2)	4.2615	.0967	.02691	.631	.592
	(3)	4.2039	.0875	.02435	.579	.543
Seminole	(1)	3.5658	.0825	.02295	.643	.614
	(2)	3.3854	.0778	.02165	.708	.676
	(3)	2.6287	.0606	.01686	.641	.613

DETERMINATION OF CALCIUM

Procedure*: The meal was prepared and ashed in a muffle furnace just as in the determination of iron. The ash was dissolved also just as in the iron determination. The solution was then diluted to 150ml., treated with 10 ml. of HCl, and a few drops of methyl orange added. It was then heated to 50 degrees and neutralized with NH_4OH with 1 ml. in excess. 10% oxalic acid was then added until the solution was acidic, and then, 12 ml. was added in excess. The solution was then boiled for one or two minutes with vigorous stirring. While still hot, 150 ml. of saturated ammonium oxalate solution[1] was added and the solution was boiled for one or two minutes and digested on a steam bath for an hour. It was then cooled to room temperature, filtered, and washed with ammonium oxalate-oxalic acid solution[2]. At this point the precipitate was ignited to the oxide, slaked, and dissolved in 40 ml. of dilute HCl[3].The solution was then diluted to 200 ml. and treated with 0.005 grams of iron as ferric chloride. Any phosphorus and manganese were removed by making the solution slightly ammonical, adding 10 ml. of bromine and digesting at a temperature a little below the boiling point for fifteen minutes. Finally 5 ml. more of bromine was added and the solution was digested for fifteen minutes longer and filtered. The precipitate was washed with ammonium chloride-ammonium

---

* This procedure was adapted from Hillebrand and Lundell. This method permits the direct separation of calcium from such elements as iron, aluminium, and phosphorus.

1. Saturated ammonium oxalate solution-- 4 percent solution.
2. Ammonium oxalate-oxalic acid solution-- 2 grams of each per liter
3. Dilute HCl-- 1:4 solution

hydroxide solution[1] and discarded. The filtrate was acidified with HCl and boiled to expel the bromine. The solution was then made slightly basic, and while still hot, sufficient 4% ammonium oxalate solution was added to precipitate all of the calcium and to provide an excess of one gram per 100 ml. of solution. The precipitate was then digested on a steam bath for one-half an hour, and then allowed to cool. At the end of two hours it was filtered, and the precipitate was washed with 5 to 10 portions of cold, neutral 0.1% ammonium oxalate solution. The precipitate was again dissolved in dilute HCl, and made slightly basic, and precipitated with oxalic acid as calcium oxalate as previously. The solution was allowed to stand two hours before the final filtering. It was then filtered and washed as previously, and ignited. The calcium was determined as calcium oxide and calculated to calcium.

1. Ammonium chloride-ammonium hydroxide solution-- 10 ml. of NH_4OH and 10 grams of NH_4Cl per liter of solution.

Table No. 13 Calcium content.

Variety		Weight of sample (dry)	Weight of CaO	Weight of Ca	Percentage Ca Dry	Air-dry
Higan	(1)	5.8936	.0228	.01636	.278*	.255
	(2)	6.1861	.0229	.01636	.264	.243
	(3)	6.4289	.0232	.01657	.258	.237
Imperial	(1)	11.4031	.0486	.0347	.304	.287
	(2)	11.6039	.0472	.0337	.290	.274
	(3)	11.7020	.0514	.0367	.313	.296
Rokusum	(1)	6.6461	.0286	.02044	.307*	.285*
	(2)	6.2490	.0202	.01446	.231	.212
	(3)	6.0642	.0178	.01272	.209	.192
Easycook	(1)	10.3939	.0300	.0214	.206	.194
	(2)	9.9611	.0276	.0197	.198	.186
	(3)	10.4163	.0242	.0173	.168**	.156**
Nanda	(1)	10.5605	.0341	.0244	.230	.218
	(2)	10.3745	.0363	.0259	.250	.236
	(3)	10.4763	.0346	.0247	.235	.222
Seminole	(1)	4.4546	.0134	.00957	.187	.181
	(2)	4.5214	.0134	.00836	.184	.178
	(3)	4.5679	.0143	.01022	.223	.188

* All of the iron and other impurities were not removed from this sample before it was precipitated as the calcium oxalate.

**A portion of this sample was lost, so its data was merely included for completeness.

DETERMINATION OF PROTEIN

As has been pointed out by previous investigators, soybeans are very rich in protein. Also much work has been done on the nature of the individual proteins in soybeans. Mashino and Shishido[1] made a study of the distribution of the nitrogen in Japanese soybeans and they obtained the following results using the Van Slyke method; amide nitrogen 9.58%, humin nitrogen 6.14%, cystine nitrogen 1.7%, arginine nitrogen 15.55%, histidine nitrogen 7.03%, lysine nitrogen 6.08%, monoamine nitrogen 49.76%, non-amino nitrogen 5.19%, and diamino nitrogen 30.40%. Other investigations have been carried out on this same problem and similar results have been obtained.

In our study the total nitrogen content was determined, and the protein content was calculated by multiplying the total nitrogen content by the conversion factor of 6.25. The method used for the determination of total nitrogen was the standard Kjeldahl Method using standard digestion equipment. Since this method is such a general one , it is not necessary to go into the actual procedure.

1. J. Soc. Chem. Ind. Japan 30, 552-60 -- 1927

Table No. 14 Nitrogen and Protein Content.

Variety	Weight of sample Dry	Weight of sample Air-Dry	ml. of HCl used	N. of HCl	% N_2	Percent Protein Dry	Percent Protein Air-Dry
Higan	3.3841	3.5637	63.65	.2314	6.09	38.06	36.20
	2.2058	2.3222	54.09	.1763	6.05	37.81	36.01
Imperial	4.9647	5.2592	93.47	.2314	6.10	38.12	36.30
	2.6694	2.8277	50.92	.2314	6.18	38.62	36.78
Rokusum	4.7330	4.9555	107.01	.1763	5.58	34.88	33.09
	2.9239	3.0614	67.10	.1763	5.66	35.37	33.58
Easycook	2.9001	3.0747	59.20	.2314	6.61	41.31	39.50
	2.0969	2.2232	42.87	.2314	6.62	41.38	39.56
Nanda	2.1837	2.3074	57.57	.1763	6.40	40.00	38.21
	2.9369	3.1029	59.73	.2314	6.58	41.12	39.30
Seminole	3.7341	3.9306	77.02	.2314	6.68	41.75	39.93
	3.7966	4.0070	77.99	.2314	6.65	41.56	39.74

DETERMINATION OF OIL

Procedure: The beans were ground to a fine flour and a sample of about 30 grams was used. The oil was extracted from this meal in Soxhlet extractors by the use of ether.* It was found that all of the oil was extracted from the bean meal in twelve hours of refluxing. This was shown by testing for complete extraction by removing the oil-ether extract and extracting for another period of two hours with a new addition of ether. No more oil was extracted if the original period of extracting had been twelve hours or longer. The ether was removed from the oil by distillation. Any remaining traces of ether were removed from the flask by attaching it to a vacuum pump to remove all vapours from the flask.

It was found that in distilling off the ether it is best to keep the temperature as low as possible, and to let the flak and contents cool thoroughly before weighing. It can be generally assumed that all traces of ether are removed when no odor of ether is obtained on agitating the contents of the flask.

---

* Ether purified for fat extraction was used in this case.

Table No. 15 Oil content.

Variety	Weight of sample Dry	Weight of sample Air-Dry	Weight of oil	Percentage Dry	Percentage Air-Dry
Higan	27.9770	28.9677	5.6153	20.07	19.38
	27.9707	28.9611	5.6346	20.14	19.44
	28.0430	29.0360	5.6462	20.13	19.43
Imperial	28.4629	29.9799	5.4784	19.24	18.27
	29.4475	31.0169	5.6397	19.15	18.17
	30.2776	31.8913	5.7367	18.94	17.97
Rokusum	30.0428	31.2521	5.0726	17.55	16.23
	30.2845	31.5037	5.3115	17.49	16.18
	29.8533	31.0551	5.4975	18.15*	16.89*
Easycook	28.8242	30.4020	5.1977	18.03	17.09
	29.1636	30.7600	5.3300	18.27	17.34
	29.4684	31.0815	5.3962	18.31	17.38
Nanda	27.4314	28.7574	5.1864	18.90	18.03
	30.0279	31.5253	5.6159	18.70	17.83
	29.1284	30.5810	5.5247	18.96	18.10
Seminole	27.2703	28.5314	4.7510	17.42	16.65
	31.2748	32.7209	5.3872	17.41	16.64
	28.8699	30.2051	4.9884	17.28	16.51

* All of the ether had not been removed from this sample.

Each variety of soybean oil studied had its own distinctive colour. In this study the oils varied in colour from a dark green to a brown. Imperial variety of soybeans produced a dark green oil. Higan variety produced a lighter green oil. Seminole variety produced a brownish-green oil. Rokusum and Nanda produced decidely brown oils. And Easycook variety produced a light brown oil. So it seems apparent that at least the colour of the oil is a function of the individual variety, and after standing for a period of three months no apparent change in colour had taken place.

"While analyses of mature soybeans for protein and oil abound in the literature, there has been relatively little reported on the different ash constituents.[1]" Much work has been done on the food values of the proteins and oils of soybeans, however analyses for the mineral content present has been sorely neglected. Woodruff and Klaas[2] have studied the iron and calcium content of the beans, however they did not make a study of the phosphorus content. Indeed analysis for the phosphorus content on all varieties here studied has not been found in the literature. Hence in our investigation we have a particular interest in the mineral content of the beans.

As has been stated previously, one of the most thorough investigations of the composition of soybeans in relation to their food value was made by Woodruff and Klaas. So it is well to make a comparison of results where the same varieties were

---

1. Woodruff and Klaas -- Univ. of Ill. Agr. Expt. Sta. Bulletin 443 -- 1938

2. ibid.

Table No. 16 Percentage composition of Mature Soybeans.
The protein, fat, calcium, iron, and phosphorus are on a dry basis.

Variety	Moisture	Protein	Oil	Calcium	Iron	Phosphorus
Higan	7.82	37.93	20.11	.265	.0071	.705
Imperial	6.18	38.37	19.11	.302	.0043	.746
Rokusum	8.11	35.12	17.52	.202	.0078	.661
Easycook	5.98	41.34	18.20	.202	.0042	.690
Nanda	6.13	40.56	18.85	.233	.0040	.602
Seminole	15.64	41.65	17.37	.186	.0065	.635
On an air-dry basis as of February 8.						
Higan	4.43	36.11	19.42	.245	.0066	.648
Imperial	5.06	36.54	18.17	.285	.0041	.700
Rokusum	3.91	33.24	16.20	.190	.0072	.608
Easycook	5.11	39.53	17.27	.190	.0040	.647
Nanda	4.78	38.75	17.98	.225	.0038	.564
Seminole	5.43	39.84	16.60	.182	.0055	.634

used. From the following table no. 17 it will be noted that the iron content as obtained by Woodruff and Klaas is much higher than that obtained by us. However Woodruff and Klaas make note of the fact that their results obtained for iron was found to be much higher than that obtained by Wu and McHargue[1]. So there is little agreement as to the percentage of iron in soybeans. However this is a variable factor. For the percentage

1. Woodruff and Klaas -- Univ. of Ill. Agr. Expt. Sta. Bulletin 443 -- 1938

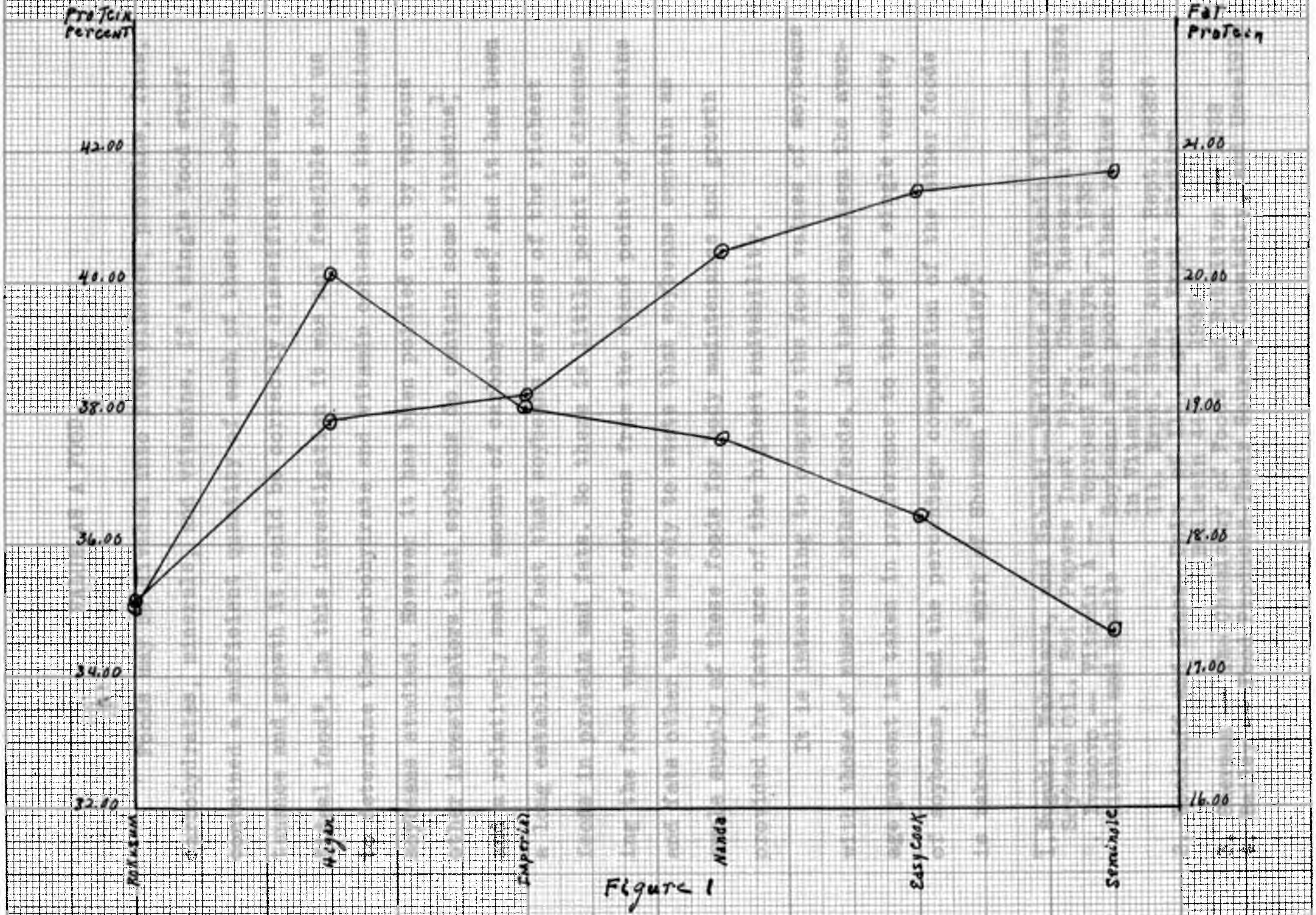
of the minerals found in any food storing substance maybe dependent to some extent upon the mineral content of the soil on which the food was grown.

Table No. 17 Comparison of results.

Variety	Protein	Fat	Calcium	Iron	Phosphorus
Imperial (W & K)	40.87	16.95	.201	.0104	---------
(Author's)	38.37	19.11	.302	.0043	.746
Easycook (W & K)	40.95	16.28	-----	----	----
(Author's)	41.34	18.20	.202	.0042	.690
Higan (W & K)	41.71	13.72	.191	.0102	-----
(Author's)	37.93	20.11	.265	.0071	.705

It has been pointed out by Lloyd and Burlison[1] that the variety of soybeans containing the larger amount of protein usually contained the smaller amount of fat. This conclusion was drawn from analyses of eighteen varieties of soybeans. However in our investigation no such correlation was found to exist. The oil content and theprotein content of the bean seems to be entirely independent of each other. And it would seem possible that this tendency as pointed out by Lloyd and Burlison just happened to exist by chance.

1. Lloyd and Burlison -- Univ. of Ill. Agr. Expt. Station Bulletin 453 -- 1939



Protein Percent
Fat Protein
42.00
40.00
38.00
36.00
34.00
32.00
21.00
20.00
19.00
18.00
17.00
16.00
Rokusun
Alger
Imperial
Manda
Easy Cook
Seminole

Figure 1

VALUE AS A FOOD

Foods may be divided into five classes; proteins, fats, carbohydrates, minerals, and vitamins. If a single food stuff contained a sufficient quantity of each of these for body maintenance and growth it could be correctly classified as the "ideal food". In this investigation it was not feasible for us to determine the carbohydrate and vitamin content of the various soybeans studied. However it has been pointed out by various other investigators that soybeans do contain some vitamins,[1] and a relatively small amount of carbohydrates.[2] And it has been a long established fact that soybeans are one of the richest foods in protein and fats. So there is little point to discussing the food value of soybeans from the stand point of proteins and fats other than merely to state that soybeans contain an ample supply of these foods for body maintenance and growth provided the fats are of the highest suitability.

It is interesting to compare the food values of soybeans with those of numerous other foods. In the comparison the average percent is taken in preference to that of a single variety of soybeans, and the percentage composition of the other foods is taken from the work of Sherman[3] and Bailey.[4]

---

1. Suguki, Nakahara, and Sahaski--Evidence of Vitamin E in Soybean Oil. Sci. Papers Inst. Phys. Chem. Research Tokyo-1934
2. Ivanovo -- Vitamin A -- Voprosui Pitaniya -- 1935
   Mitchell and Beadle -- Soybeans are poorer than yellow corn in Vitamin A. Ill. Expt. Sta. Annul. Rept. 19256
2. Woodruff and Klaas--Univ. of Ill. Agri. Expt. Station Bulletin 443 -- 1938
3. Sherman -- The Chemistry of Foods and Nutrition -- 1938
4. Bailey -- Food Products-Their Source, Chemistry, and Use-1928

Table No. 18 Comparison of the food values of soybeans with those of numerous other foods.

Food	Percent Protein	Percent Fat	Percent Calcium	Percent Iron	Percent Phosphorus
Soybeans	39.16	18.52	.231	.0056	.673
Milk	8.46	10.65	.118	.003	.093
Eggs	14.80	10.50	.063	.0031	.224
Wheat (Whole)	12.20	1.74	.053	.005	.374
Lean Beef	66.92	12.23	.013	.002	.204
Potatoes	2.40	.10	.013	.0012	.053
Corn	9.88	4.17	----	-----	----
Rice (Brown)	6.80	2.00	.065	.0009	.336
Peanuts	25.80	38.60	.056	.00198	.391
Turnips	3.20	.20	.056	.0005	.047
Carrots	2.60	.30	.045	.0006	.041
Beets	3.50	.10	.028	.0008	.042
Apples	.60	.50	.007	.00036	.012
Bananas	1.20	.20	.008	.0006	.028
Peas (dried)	24.60	1.00	----	.0057	.463

From the preceding table it is evident that soybeans are not only a good source of protein and fat, but also of the mineral foods, (iron, calcium, and phosphorus) which are a necessary constituent of nutrition, as well. Also from the table it would seem that a flour prepared from soybeans would be much richer in protein, fat, calcium, iron, and phosphorus than that prepared from any of the other common sources such as corn and wheat. However, as pointed out previously, soybean flour would contain a relatively small amount of carbohydrates, and for this reason an adequate supply of this food substance would have to come from some other source. Due to the fact that soybean flour contains such a small amount of carbohydrates it is used to some extent as a food for dibetic patients.

With edible soybeans being adaptable to this type of soil, and with their relatively high nutritional value, they should come to play a much more important role in the common diet. But it is not expected that soybean flour and other products will come into use, as may be said, "over night", for it is only natural that as a food one has to develop a taste for it. After a taste is once developed, however, for this bean; it should serve as one of our most common foods in a low-cost diet. However, as has been previously stated, the type of bean grown for food is going to depend upon the palatability of the bean by the individual. Thus no one edible variety can be recommended at the exclusion of any of the others. However, on the whole, due to soybeans having such a high protein, fat, and mineral food value, they should come to rival such common food stuff as wheat and corn in their economic food importance.

CONCLUSIONS

1. We have learned that edible soybeans are rather well adapted to North Georgia conditions, and give a fair yield for beans of this sort.
2. We have confirmed the adequacy of the Hillebrand and Lundell method for the determination of calcium in the presence of phosphorus and iron.
3. We are able to report here apparently for the first time the mineral content of three varieties of edible soybeans; Rokusum, Nanda, and Seminole.
4. Our results are in agreement with those of Woodruff and Klaas of the University of Illinois as regards the relative amounts of proteins and fats. The only great exception being that of the fat content of the Higan variety of soybeans, and with this variety Woodruff and Klaas obtained 13% fat whereas, we obtained 20% fat. As regards to the calcium content, our results are higher than those of Woodruff and Klaas, but with iron their results are nearly twice as great as ours.
5. The negative fat-protein ratio, as pointed out by Lloyd and Burlison, was not found to exist in these beans.
6. Since the literature shows that scarcely any determinations have been made previously on the phosphorus content of soybeans, we have thus added to our knowledge of the phosphorus content of these beans.
7. As would be expected, oil of different varieties of soybeans differ in characteristics such as color.

8. In so far as mineral content goes, soybeans compare favorably with most of the stable food substances. And in proteins they usually excel most common foods such as cerals and peanuts.
9. Recently noteworthy investigations have been carried out on peanuts in Georgia. It is known that peanuts contain about 38.6% fat while, soybeans contain only about 18.5% fat, and peanuts give a higher yield per acre in bushels; but soybeans contain about 39.2% protein whereas, peanuts contain only about 25.8% protein. And proteins are the most expensive constituent of the common diet.
10. It is inferred that a more widespread use of soybeans in Southern diets is advantageous both from the standpoint of nutrition and economy.

Bibliography

Bulletins

Beeson, K.E., Soybeans in Indiana . Extension work in Agriculture and Home Economics, Purdue Univ. Extension Bulletin No. 231, 1938

Grove, E.W., Soybeans in the United States; Recent Trends and Present Economic Status. U.S. Dept. of Agriculture Washington, D.C. Bulletin No. 619, 1938

Hilton, J.H., Wilbur, J.W., and Hauge, S.M., Ground Soybeans and Linseed Oil-Meal for Growing Dairy Calves. Purdue Univ. Agri. Expt. Sta. Bulletin No. 351, 1931

Jenkins, Soybeans. Conn. Agri. Expt. Sta., Bulletin No. 179, 3-13, 1938

Lloyd, J.W., and Burlison, W.L., Eighteen Varieties of Edible Soybeans. Univ. of Ill. Agri. Expt. Sta. Bulletin No. 453, 1938

Morse, J.W. Soybean Utilization. U.S. Dept. of Agriculture Farmer's Bulletin No. 1617, 1932

Morse, J.W., Soy Beans: Culture and Varieties. U.S. Dept. of Agriculture. Farmer's Bulletin No. 1520

Vestal and Shrewsbury, Nutritive Value and Mineral Deficiences. Ind. Agri. Expt. Sta. Purdue. Bulletin No. 420, 1937

Whiteman, E.F. and Keyt, E.K., Soybeans for the Table. U.S. Dept. of Agriculture. Leaflet No. 166

Woodruff, S. and Klaas, H., A Study of Soybeans with Reference to Their Use as Food. Univ. of Ill. Agri. Expt. Sta. Bulletin No. 443, 1938

Woodworth, Illini Soybean. Univ. of Ill. Agri. Expt. Sta. Bulletin No. 335, 1926

Articles

Adolph and Chao, "Utilization of Calcium in Soybean Diets." J. Nutritions 5, 379, 1932

Annen, "The Soybean. Its Value as a German Foodstuff." Muhlenlab, 1933

Burlison, W.L., "The Soybean" J. Tenn. Acad. Sci. 28, 772-7, 1936

Cox, "Soybean Analysis" Oil and Soap 13, 167-8, 1936

Daniels and Nichols, "Nutritive Value of Soybeans". J. Biol. Chem. 32, 91-102, 1917

Dittes, "The Soybean as a Human Food". J. Tenn. Acad. Sci. 8, 323-25, 1935

Ducceschi, "Utilization of Soybeans as a Human Food." Biochem. terap. sper. 14, 400-2, 1927

Earle and Mitner, "The Occurrence of Phosphorus in Soybeans." Oil and Soaps 15, 41-2, 1938

Eastman, "Industrial Utilization of Soybean Oil Meal." Chem. Review 94 No. 5

Ernst, "A Comparison of the Nutritive Properties of Soybean Milk and Cow's Milk." Chinses J. Physiol. 3, 353-62, 1929

Goff, "Soybeans, A Valuable Food for Diabetics." Pepret Pharm. 1920

Holmes, "Digestibility of Steam Cooked Soybeans." J. AM. Med. Assoc. 6, 40-9, 1929

Howath, "The Soybean as Human Food." Chinese Govt. Bureau of Economic Information. 1927

Mashino and Shigunsk, "Nitrogen Distribution of Soybean Protein." J. Soc. Chem. Ind. Japan. 1927

Mitchell and Beadles, "Soybeans are poorer than Yellow Corn in Vitamin A." Ill. Agri. Sta. Ann. Rept. 19356, 1938

Shita and Yanagigawa, "The Amino Acids of Soybean Meal." Repts. Imp. Ind. Res. Inst. Osaka, Japan. 1936

Sking Wan, "Comparison of Soybeans and Milk in Vitamins B_1 and B_2." Chinese J. Physiol.

Street and Bailey, "The Carbohydrates and Enzymes of Soybeans." J. Ind. Eng. Chem. 785, 3-8, 1915

Tuck, Marrison, and Maynard, "The Nutritive Values of the Proteins of Soybean Oil Meal." J. Agri. Research 51, 401-2, 1935

Wastl, "The Stable Soybean Meal, A Future Human Food." Chem. Rundschau Mitteleuropa Balkan, 1927

Books

Horvath, A.A. The Soybean Industry. 1938